Extending the 2-Meter OWA Family
Part 3: Increasing OWA Gain vs. Preserving Sidelobe Suppression

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In our preceding discussion, we developed tentative answers to two out of our three inquires that emerged from the extension of the OWA 2-meter family to 20 elements. By way of quick review, the low gain but high sidelobe suppression of the 20-element version of the array left us with these questions.

- 1. Which of the two OWA design concepts--the core or the method of adding new elements--has the dominant effect on side-lobe development?
- 2. Is there a method of obtaining more gain from the OWA series without sacrificing sidelobe suppression and attenuation?
- 3. What role does element population play in sidelobe attenuation?

The development of some hybrid models, combining the core of the OWA Yagi with the forward director structures of DL6WU and VK3AUU designs, suggested strongly that the forward director structure more than the core is responsible for the strong sidelobe attenuation. As well a key to sidelobe attenuation appears to be a higher density of well-regulated directors than has typically been used on past (pre-VK3AUU) long-boom Yagi designs.

Although incidental to the exercise, I would not especially recommend the use of the hybrid designs in practice. The DL6WU design and some of its peer designs provided the most wide-band gain for the fewest elements. For sidelobe attenuation, the VK3AUU array--even severely modified to fit this exercise--is a good standard for future designs.

We are thus left with only one question: whether it is possible to obtain more gain from the OWA 20-element Yagi without significant damage to its sidelobe suppression abilities. As a guide to the level of sidelobe development in the various arrays, the sample DL6WU design in its 4-mm element diameter version averaged a front-to-sidelobe ratio of 16.8 dB, while the version with 11.8-mm elements averaged 17.0 dB. The 0.1875" element diameter version of the VK3AUU array achieved an average front-to-sidelobe ratio of about 22.2 dB, or 5 dB better than the DL6WU. The OWA 20-element Yagi, despite a gain deficit of about 1-3/4 dB relative to the other arrays managed an average front-to-sidelobe ratio of 28.7 dB, about 6.5 dB better than the VK3AUU array and 11.5 dB better than the DL6WU.

If sidelobe suppression is important to any application of a long boom Yagi, then we would accrue an advantage if we could squeeze further gain from the OWA array without losing a significant amount of the sidelobe attenuation. As well, we should recall that the OWA Yagi not only attenuates sidelobes, but also tends to suppress them, since we could observe fewer sidelobes--either forward or rearward--on the OWA pattern than on the patterns for the other arrays.

Sidelobe suppression may not be so straightforward as we might initially think from pattern observation. All of the anticipated 6 sidelobes for a 6-wavelength boom may be present. However, if the array's structure directs one or more of them so that two or more coincide, then the seemingly suppressed sidelobes will be present, but weak and invisible. This possibility, however, has little practical difference from true suppression, since it is the shape of the resulting pattern and the strength of the visible sidelobes that will determine an array's sensitivity to signals that are off axis.

How OWA Gain and Sidelobe Attenuation May Be Related

A Yagi array consists, normally, of a driven element and one or more parasitic elements, that is, elements which derive the energy directly or indirectly from the driven element. Since the intent of a Yagi is to provide a directional beam of energy, those elements on the side of the array away from the main forward beam are called reflectors. In the most common designs, there will be a single reflector, since its task is less to reflect and more to set--by virtue of its spacing and length--the feedpoint impedance of the driver. In large arrays, the reflector is normally more influential on the performance at the low end of the desired passband than the upper. We can also add other reflector elements, ordinarily in a plane at right angles to the orientation of the remaining elements. By creating a planar reflector, we can improve the front-to-back ratio of the array. This improvement often shows up in the attenuation of vertical sidelobes--a subject for a wholly different treatise.

Elements forward of the driver in the direction of the main beam are called directors. We may add a virtually endless number of directors ahead of the driver. Before we turn to these forward directors, let's pause to note some special relationships. The first director in a narrow band Yagi tends to function solely as a director. The driver maintains the highest current magnitude throughout the passband of the array. In wide-band designs, however, the first director normally has a position closer to the driver. In the upper portion of the passband, the first director will show a higher relative current magnitude than the driver itself and thus tends to control the performance of the array in that region of the passband. With certain spaces between the driver proper and the first director as a secondary driver--due to the close element coupling--we may even see a reversal of normal expectations for driver feedpoint reactance. That is, as we shorten the first director, we may find the reactance at the driver feedpoint becoming less capacitive and more inductive. In the OWA design, the 2nd and 3rd directors perform controlling functions and may be the same length--or the 3rd director may be slightly longer than the 2nd director. The controlling function receives its name from the ability of the OWA design to center the peak gain and the peak front-to-back ratio close to the design frequency and within the operating passband.

Beyond the 3rd director, the remaining forward directors generally show a regular--although not necessarily simple--progression of reduced lengths until we reach the end of the array. Some director pairs may be the same length, but the general tendency is reduced length as we move away from the driver. The result is an overall taper of the Yagi shape for a given boom length.

As Lawson showed, the basic forward gain of a Yagi is determined less by the absolute number of elements and more by the boom length. For a given boom length, of course, we require a certain minimum number of elements to achieve the mutual or inter-element coupling necessary to establish current levels on the entire set of directors that allow us to obtain the gain that is theoretically possible. One of the prices that we pay for using a minimalist configuration is a narrow operating passband, not only in terms of the feedpoint impedance excursions, but as well in terms of the available gain and front-to-back ratio.

Wide-band designs, such as the DL6WU and VK3AUU Yagi series, free the home Yagi builder from many of the ultra-precise construction tasks that face someone building a narrow-band design with a minimalist configuration. The cost is twofold: the use of more elements and the use of a relatively mild taper to the element lengths. The 6-wavelength boom of a DL6WU array uses a taper in the range of 0.79 to 0.83 as we take the ratio of the most forward director to the reflector. The 25-element VK3AUU array on the same length boom uses a taper on the vicinity of 0.78.

As we discovered in the last episode, even within the realm of wide-band designs, we can distinguish minimal from "fully-packed" Yagi designs. The DL6WU design--and a number of kindred Yagis--achieve maximum wide-band gain from the fewest practical number of elements, but suffer fairly large fully developed sets of forward and rearward sidelobes. On the same boom length, the addition of 5 directors, using the VK3AUU algorithm, attenuates sidelobes by an average across the 2-meter band of 5 dB relative to the DL6WU design. In fact, compressing the DL6WU director structure to allow the addition of 3 more directors shows a sidelobe attenuation level close to that of the VK3AUU design.

For a given gentle taper in the range of the DL6WU and VK3AUU Yagi designs, gain is largely a function of boom length, since both element populations achieve similar gain levels. Both arrays achieve within their design algorithms comparable levels of mutual coupling from one element to the next. However, the 20-element OWA Yagi achieved considerable less gain, but accompanied by not only further attenuation of sidelobe energy, but as well by an apparent suppression of sidelobes. Moreover, most of the forward director structure uses element spacing that is quite similar to that in the DL6WU design. The next step is to search for a critical difference.

The most evident difference lies in the overall element taper of the two arrays. Instead of a 0.79-0.83 taper, typical of DL6WU 6-wavelength arrays, the OWA series array shows a taper close to 0.67--a much more radical level of element shortening as we move forward along the beam. One obvious effect of the more radical tapering of element lengths is to reduce the mutual coupling among adjacent elements, which plays a key role in the reduced additional gain that we achieve with each added director. **Fig. 1** shows the OWA outline with the relative current magnitude levels indicated for each element.

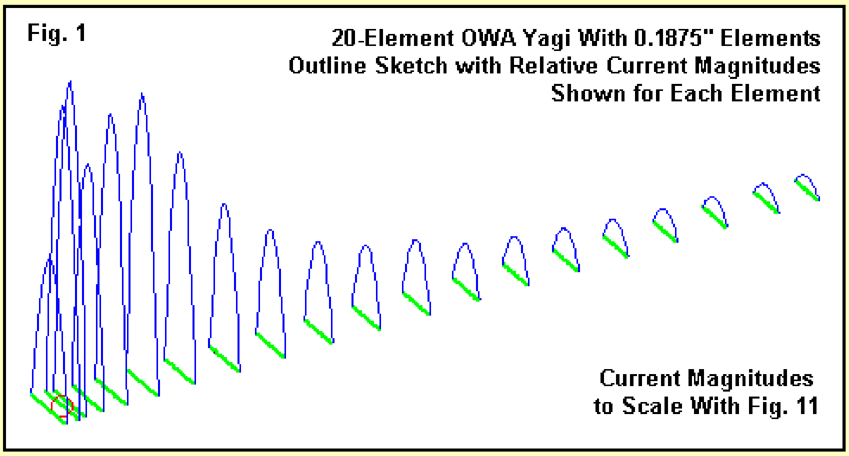

Fig. 1

20-Element OWA Yagi With 0.1875" Elements
Outline Sketch with Relative Current Magnitudes
Shown for Each Element

Current Magnitudes
to Scale With Fig. 11

The first line of correction might seem to be to simply increase the mutual coupling between elements. However, as we shall see in our efforts to restore some of the lost gain to the OWA 20-element, the element taper will play a considerable role in sidelobe formation. Although we shall not go all the way in restoring gain, we shall go far enough to illustrate some of the limitations that we encounter along the way. Understanding limitations of Yagi design is significant to the design of series that attempt to combine across a given operating passband maximum forward gain, maximum front-to-back ratio, minimum feedpoint SWR, and minimum sidelobe development.

Standard Element Scaling The first inclination might be to use fatter elements in an effort to achieve a higher level of mutual element coupling. Of course, a change in element diameter requires that we re-calculate the element lengths. The standard equations involve a 2-step process. The first step is to calculate the reactance of each element from this following equation.

$$X=\left[430.3\log_{10}\left(\frac{2\lambda}{D}\right)-320\right]\cdot\left(\frac{2L}{\lambda}-1\right)+40\,\Omega \qquad (1)$$

L is the original element length, D is the original element diameter, lambda is a wavelength at the design frequency, and X is the resulting reactance. Then we plug the calculated reactance along with lambda and a new element diameter, D, into the second equation.

$$L=\left[\frac{(X-40)}{430.3\log_{10}\left(\frac{2\lambda}{D}\right)-320}+1\right]\cdot\frac{\lambda}{2} \qquad (2)$$

The result is a new length, L, applicable to the new element diameter.

These handy equations are part of the HAMCALC suite of GW Basic utilities--now available for download from the *CQ Magazine* web site. Let's use them to design revised versions of the 20-element OWA Yagi using 0.375" and 0.75" diameter elements. The following table shows the results of the re-design.

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20-Element OWA Yagis: Scaled Element Lengths and Spacing

Note: All dimensions derived from standard element scaling equations while maintaining the same element spacing. All dimensions in inches.

	Cumulative	**Element Diameter**		
Element	**Spacing**	**0.1875"**	**0.375"**	**0.75"**
Refl.	**----**	**40.90**	**40.98**	**41.08**
Driver	**8.79**	**39.50**	**39.35**	**39.15**
Dir. 1	**13.47**	**37.00**	**36.46**	**35.71**
Dir. 2	**25.38**	**36.33**	**35.68**	**34.78**

Dir. 3	40.72	36.40	35.76	34.88
Dir. 4	61.38	36.21	35.54	34.62
Dir. 5	86.49	35.20	34.37	33.22
Dir. 6	116.00	34.30	33.33	31.98
Dir. 7	146.60	33.60	32.51	31.02
Dir. 8	178.40	32.90	31.70	30.05
Dir. 9	210.00	32.20	30.89	29.09
Dir. 10	243.00	32.20	30.89	29.09
Dir. 11	276.00	30.80	29.27	27.16
Dir. 12	309.00	30.40	28.82	26.61
Dir. 13	342.00	30.00	28.34	26.05
Dir. 14	375.00	29.20	27.41	24.95
Dir. 15	408.00	28.80	26.95	24.40
Dir. 16	441.00	28.40	26.49	23.85
Dir. 17	475.00	28.40	26.49	23.85
Dir. 18	502.00	27.40	25.33	22.47

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The results of this exercise should theoretically net us the same performance from each version of the array, since the equations will yield the same inter-element coupling, using shorter lengths for fatter elements and the original element spacing throughout the array. The following table indicates a somewhat different story.

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Modeled Performance: 20-Element OWA Yagi: Standard Element Scaling

0.1875" Diameter Elements

Parameter	144 MHz	146 MHz	148 MHz
Gain dBi	15.19	15.61	15.68
180-deg F-B	24.50	26.18	26.74
Front-Sidelobe	28.26	31.07	26.74
Impedance (R+/-jX)	42.9 + j 4.5	46.8 + j 6.9	45.1 - j 3.9
50-Ohm SWR	1.20	1.16	1.14

0.375" Diameter Elements

Parameter	144 MHz	146 MHz	148 MHz
Gain dBi	15.18	15.51	15.52
180-deg F-B	24.81	25.86	24.37
Front-Sidelobe	32.15	30.44	26.11
Impedance (R+/-jX)	43.7 + j 5.0	47.2 + j 4.8	40.0 - j 7.9
50-Ohm SWR	1.19	1.12	1.32

0.75" Diameter Elements

Parameter	144 MHz	146 MHz	148 MHz
Gain dBi	15.07	15.30	15.24
180-deg F-B	24.74	25.06	23.43
Front-Sidelobe	31.86	29.48	25.39
Impedance (R+/-jX)	44.4 + j 4.3	46.6 + j 0.4	33.2 - j 9.1
50-Ohm SWR	1.16	1.07	1.59

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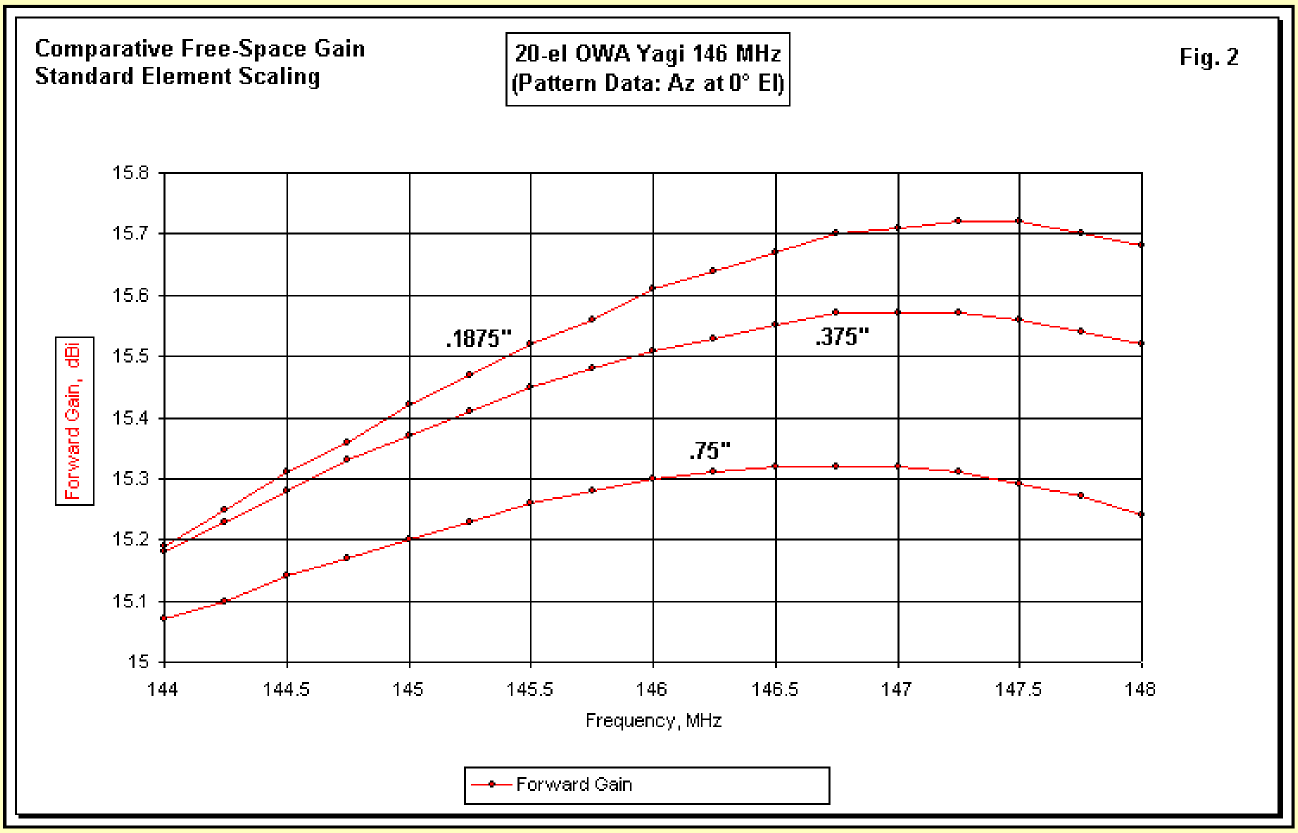
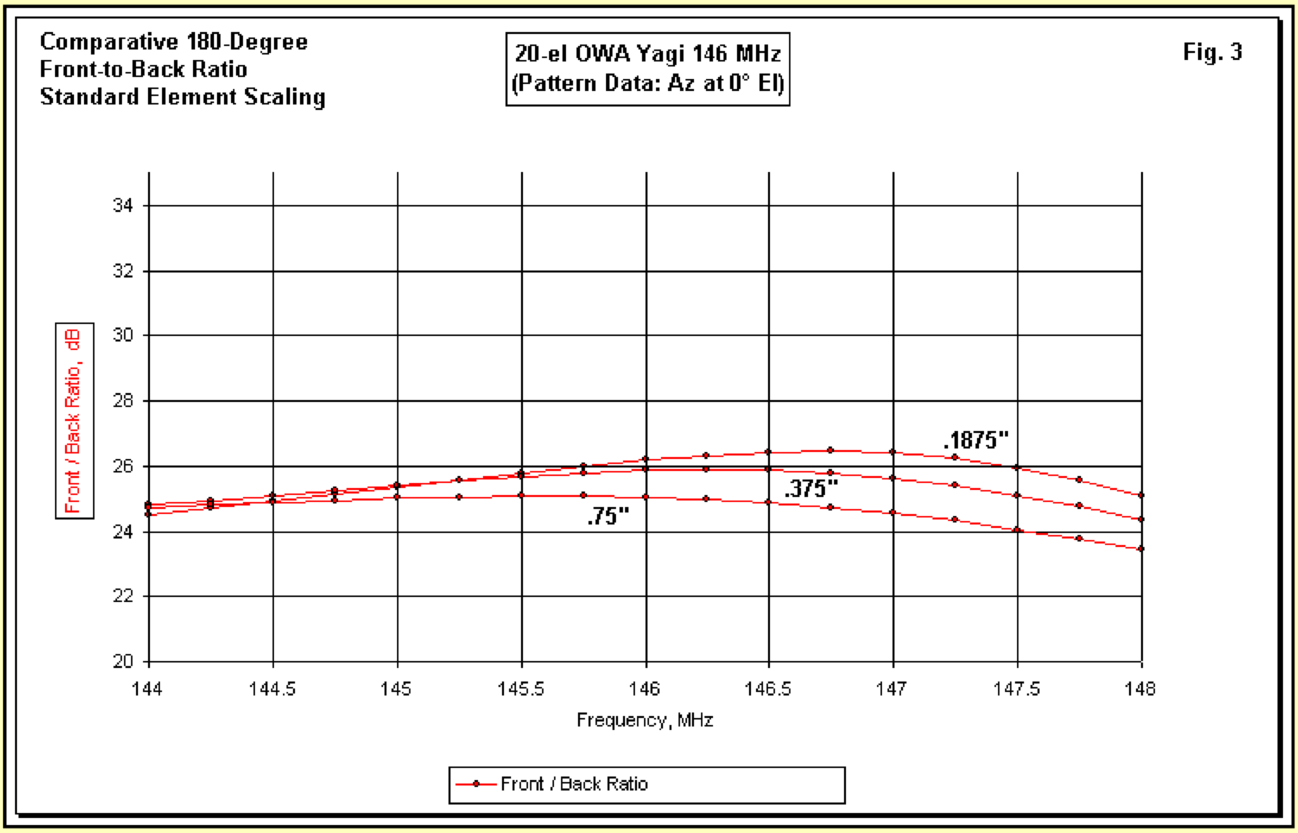
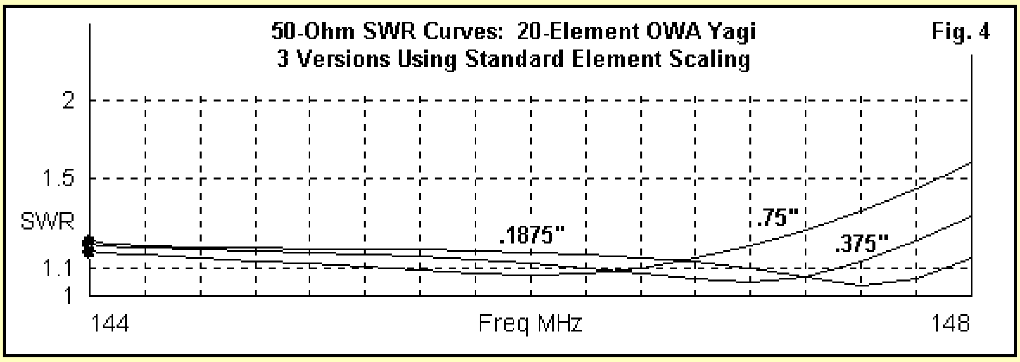
Although we see a decreasing gain as we increase the element diameter, **Fig. 2** makes the decrease more readily apparent. With each doubling of element diameter, we end up with increasingly less gain.



However, the front-to-back ratios do not significantly differ among the variations of the 20-element OWA Yagi. As **Fig. 3** shows, the decline from one diameter to the next larger is much less noticeable than the change in gain.

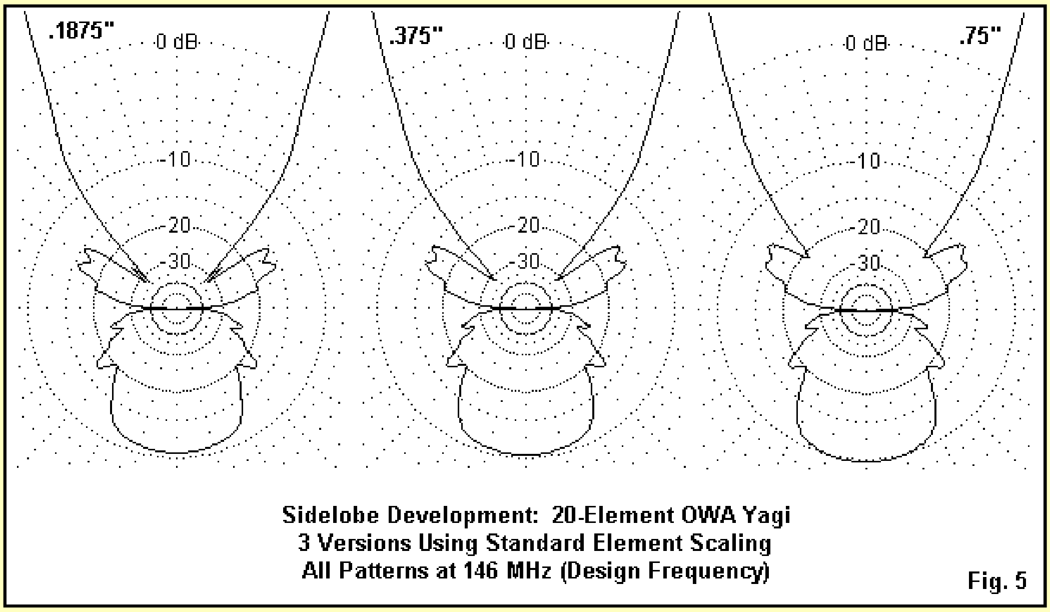


Part of the problem stems from the limitations of the equations themselves. They work best--achieving very close to perfectly equivalent arrays--when the ratio of the two elements is 1.5:1 or less. We have pushed the equations to 2:1 and 4:1 ratios. As well, the OWA core requires somewhat careful optimizing of the driver and first director (especially) to hold the passband within the same limits. Without this adjustment, the SWR passband slides downward in frequency with increasing element diameter. **Fig. 4** makes this slide readily apparent.



50-Ohm SWR Curves: 20-Element OWA Yagi
3 Versions Using Standard Element Scaling
Fig. 4

In the process of using standard conventions for adjusting the element lengths for the new diameters, we did alter another--often overlooked--feature of the array. We increased the rate of taper of the array, as indicated by the ratio of the most forward director length to the reflector length. The 0.375" version shows a taper ratio of 0.62, while the 0.75" version has a ratio of 0.55. The significance of these further reductions appears in **Fig. 5**, which shows the 146-MHz sidelobe structure for free-space models of the three array versions.



Sidelobe Development: 20-Element OWA Yagi
3 Versions Using Standard Element Scaling
All Patterns at 146 MHz (Design Frequency)
Fig. 5

Although the 0.1875" version clearly shows a 4th forward sidelobe, despite its minuscule size, the fatter versions of the array with their increased taper obscure any definite identification of a 4th forward lobe. Since the overall sidelobe attenuation is not better than with the thinnest of our Yagis, the apparent disappearance of the 4th sidelobe has little practical consequence. However, the progression does suggest that element length taper does play a role in sidelobe formation and suppression.

An Alternative Technique of Increasing Mutual Coupling

There is a second strategy available for scaling the element lengths for fatter elements. We can initially substitute the new element diameter for the old. The resulting array will no longer show its performance peak or its passband limits at the same frequency as the original array. However, we can locate those limits and then re-scale the entire array so that the design frequency is once again 146 MHz.

The 20-element OWA Yagi underwent this treatment, with 4 versions as the result: the original 0.1875" diameter array plus three others using 0.375", 0.5" and 0.75" diameter elements. The following table shows the dimensions that resulted from the exercise.

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20-Element OWA Yagis: Compressed Element Length Adjustments

Note: Element lengths and spacing derived from scaling and compression techniques described in the text. All dimensions in inches.

Element	**Cumulative Spacing**	**El. Dia. 0.1875"**	**Cumulative Spacing**	**El. Dia. 0.375"**
Reflector	**----**	**40.90**	**----**	**40.19**
Driver	**8.79**	**39.50**	**8.64**	**38.81**
Director 1	**13.47**	**37.00**	**13.24**	**36.36**
Director 2	**25.38**	**36.33**	**24.94**	**35.69**

Director 3	40.72	36.40	40.01	35.76
Director 4	61.38	36.21	60.31	35.58
Director 5	86.49	35.20	84.98	34.59
Director 6	116.00	34.30	113.98	33.70
Director 7	146.00	33.60	144.04	33.01
Director 8	178.40	32.90	175.29	32.33
Director 9	210.00	32.20	206.34	31.64
Director 10	243.00	32.20	238.76	31.64
Director 11	276.00	30.80	271.19	30.26
Director 12	309.00	30.40	303.61	29.87
Director 13	342.00	30.00	336.04	29.48
Director 14	375.00	29.20	368.46	28.69
Director 15	408.00	28.80	400.88	28.30
Director 16	441.00	28.40	433.31	27.90
Director 17	475.00	28.40	466.72	27.90
Director 18	502.00	27.40	493.25	26.92

Element	Cumulative Spacing	El. Dia. 0.5"	Cumulative Spacing	El. Dia. 0.75"
Reflector	----	39.85	----	39.31
Driver	8.57	38.48	8.45	37.96
Director 1	13.12	36.05	12.95	35.56
Director 2	24.73	35.39	24.39	34.91
Director 3	39.67	35.46	39.14	34.98
Director 4	59.80	35.28	58.99	34.80
Director 5	84.26	34.29	83.12	33.83
Director 6	113.01	33.42	111.49	32.97
Director 7	142.82	32.73	140.89	32.29
Director 8	173.81	32.05	171.46	31.62
Director 9	204.59	31.37	201.83	30.95
Director 10	236.74	31.37	233.54	30.95
Director 11	268.89	30.01	265.26	29.60
Director 12	301.04	29.62	296.97	29.22
Director 13	333.19	29.23	328.69	28.83
Director 14	365.34	28.45	360.41	28.06
Director 15	397.49	28.06	392.12	27.68
Director 16	429.64	27.67	423.84	27.29
Director 17	462.77	27.67	456.51	27.29
Director 18	489.07	26.69	482.46	26.33

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Since each new array involved total frequency scaling, including element spacing, each version requires a cumulative spacing column as well as an element length column. The compression scaling name results from the fact that the scaling results in slightly shorter boom lengths for each fatter version. Hence, besides the effects of increasing the element diameters, we also have very slightly closer element spacing at work in increasing the mutual coupling among elements. The following table summarizes the modeled free-space performance data for the 4 versions of the array.

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Modeled Performance: 20-Element OWA Yagi: Compressed Element Scaling

0.1875" Diameter Elements: Boom length 6.21 wavelengths

Parameter	144 MHz	146 MHz	148 MHz
Gain dBi	15.19	15.61	15.68
180-deg F-B	24.50	26.18	26.74
Front-Sidelobe	28.26	31.07	26.74
Impedance (R+/-jX)	42.9 + j 4.5	46.8 + j 6.9	45.1 - j 3.9
50-Ohm SWR	1.20	1.16	1.14

0.375" Diameter Elements: Boom length 6.18 wavelengths

Parameter	144 MHz	146 MHz	148 MHz
Gain dBi	15.72	16.07	16.07
180-deg F-B	23.31	26.29	26.35
Front-Sidelobe	31.35	30.76	26.85
Impedance (R+/-jX)	36.5 - j 0.5	41.0 + j 2.6	46.3 - j 7.2
50-Ohm SWR	1.37	1.29	1.18

0.5" Diameter Elements: Boom length 6.05 wavelengths

Parameter	144 MHz	146 MHz	148 MHz
Gain dBi	15.95	16.25	16.20
180-deg F-B	22.59	25.88	26.70
Front-Sidelobe	32.91	30.54	24.17
Impedance (R+/-jX)	33.7 - j 1.8	38.3 + j 1.3	45.7 - j 9.2
50-Ohm SWR	1.49	1.31	1.24

0.75" Diameter Elements: Boom length 5.97 wavelengths

Parameter	144 MHz	146 MHz	148 MHz
Gain dBi	16.25	16.48	16.34
180-deg F-B	21.54	24.70	27.07
Front-Sidelobe	24.16*	28.78*	23.82
Impedance (R+/-jX)	29.6 - j 4.3	34.1 - j 0.5	44.5 - j12.8
50-Ohm SWR	1.71	1.47	1.33

Note: * means the appearance of a new sidelobe.

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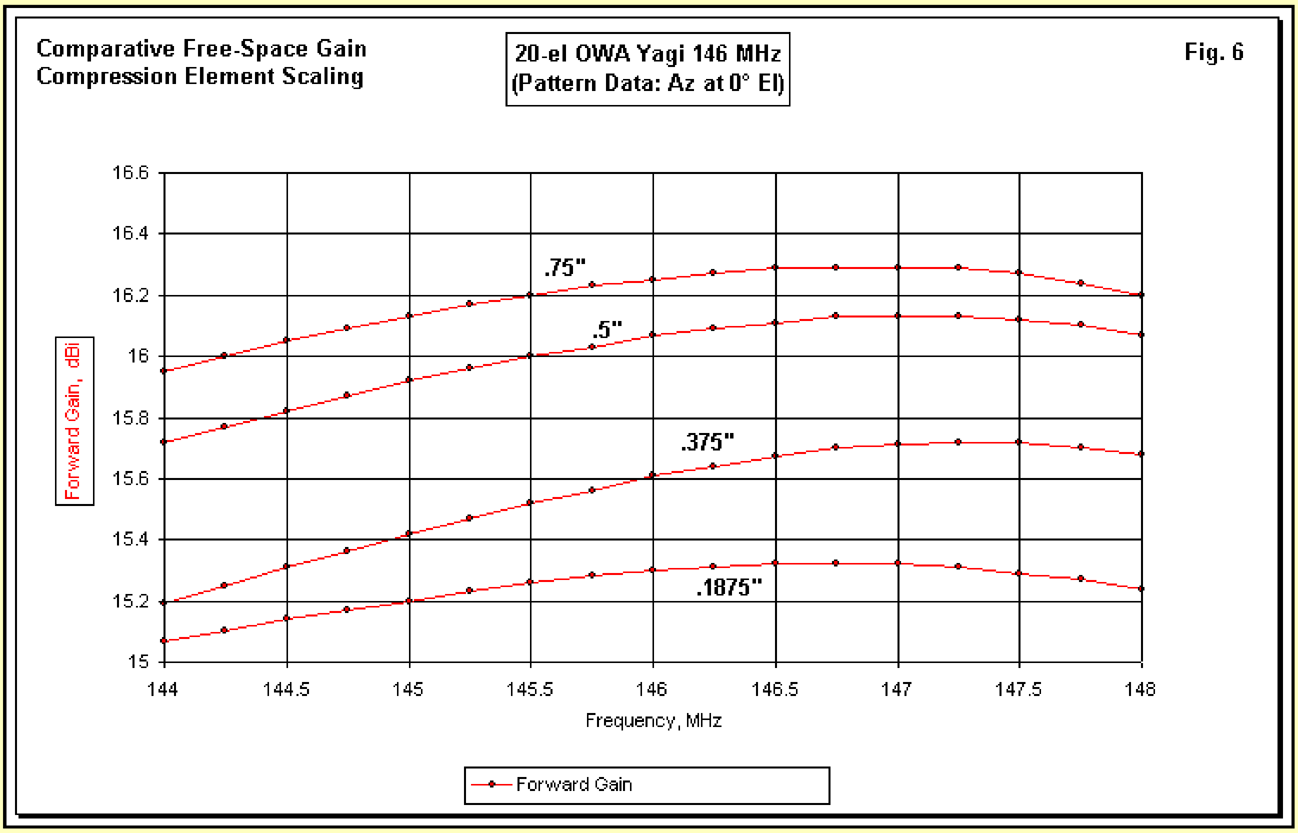
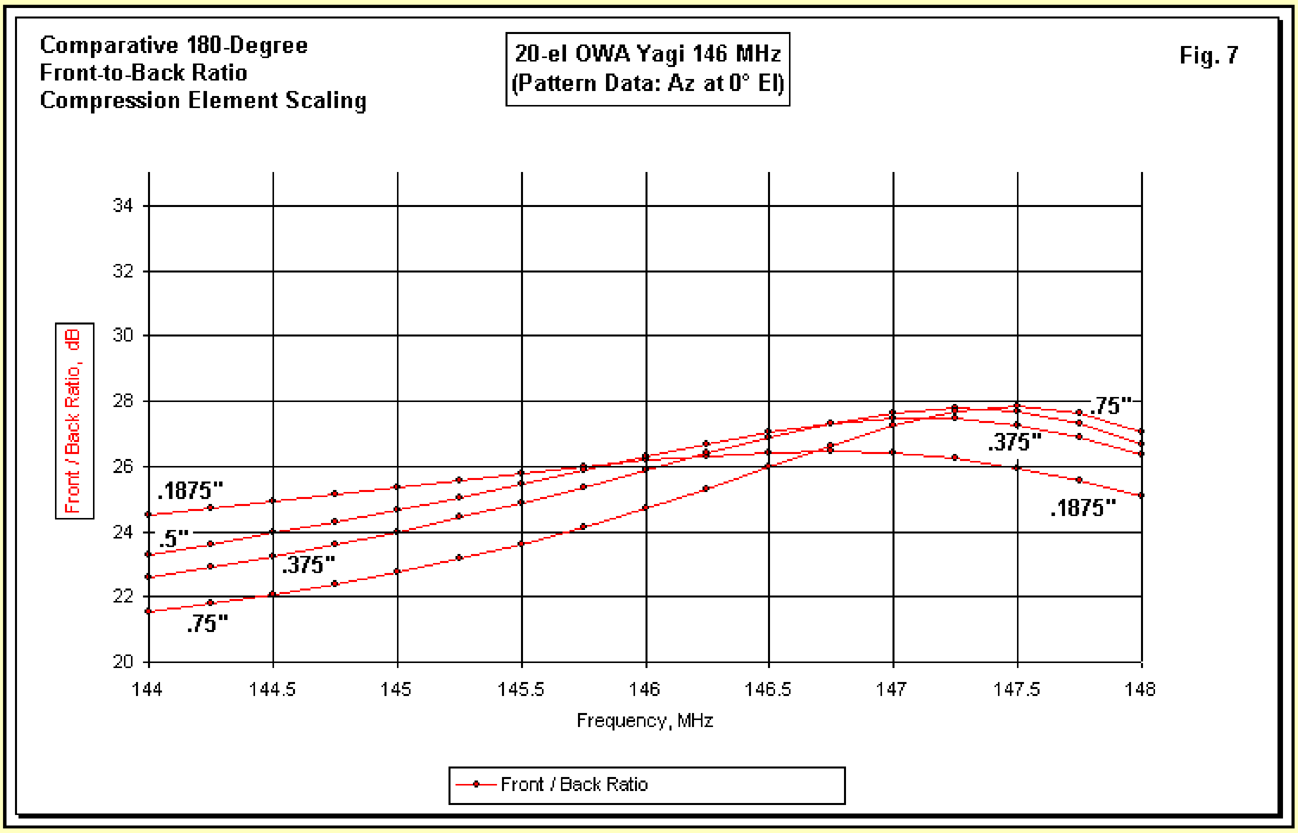
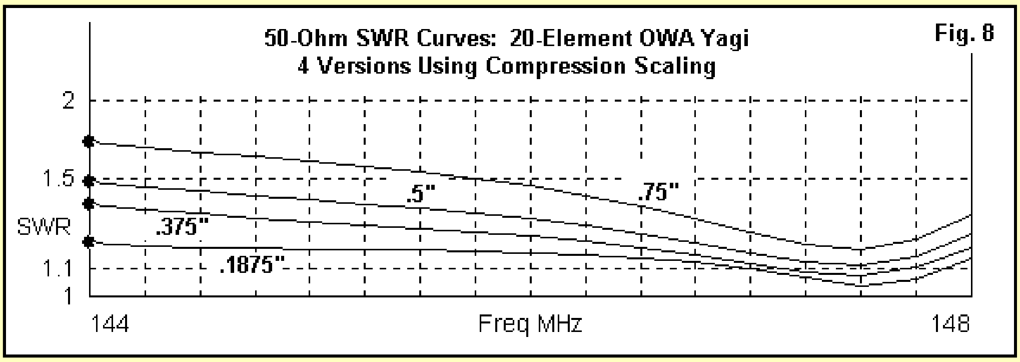


Fig. 6 shows us the gain curves for all 4 versions of the compression-scaled array. Since the exact passband limits used in the scaling is a judgement call and not a simple calculation, we should not expect a perfectly congruent set of curves. However, all of them place the gain peak well within the operating passband. It is clear that increasing the element diameter increases the gain. In just the range of the trial diameters, we have restored the peak gain to within about 1 dB of the gain achieved by DL6WU and VK3AUU arrays. We have not made our array very much heavier in the process, since 3/8" 6061-T832 tubing is actually lighter per unit length than 3/16" rod.

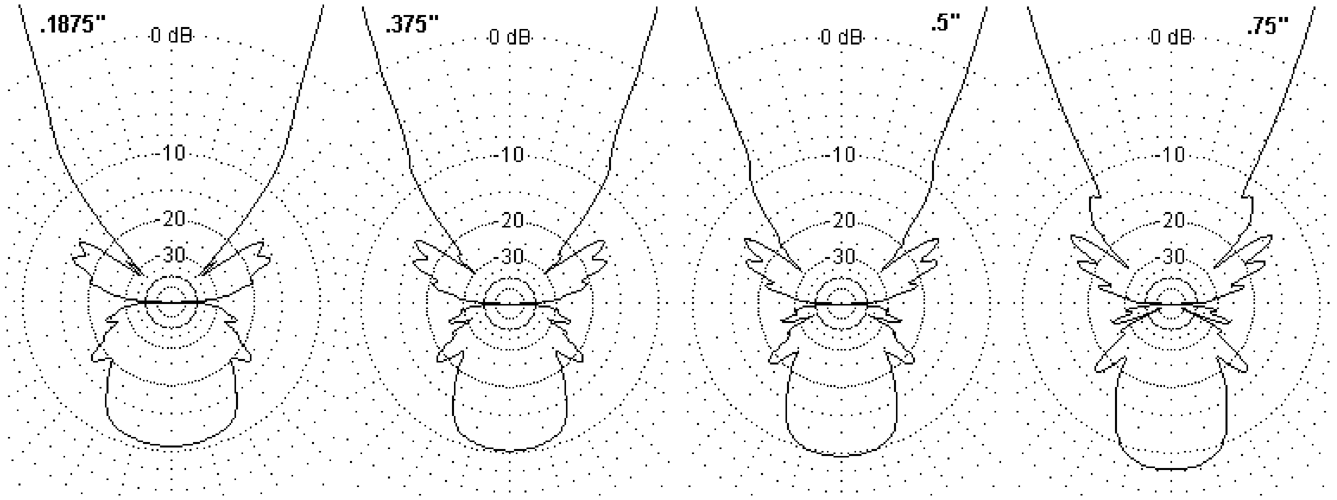


The front-to-back ratio data, shown in **Fig. 7**, suggests that we have made no operationally significant changes in this performance category. The exact peak position is a function of the scaling choices made, and one might easily align all of the peaks by slightly different selections. In general, I chose to scale the array versions so that the SWR curves would align their minimum values with fair coincidence. In addition, I also selected the scaling factors to achieve the same taper factor for each version.



As **Fig. 8** shows, all of the arrays have minimum 50-Ohm SWR values at about 147.5 MHz. Although all versions of the array have passband end-to-end SWR values well below 2:1, the overall SWR curves degrade as we increase the element diameter without further adjustment to the core of the array.

If we take sidelobe suppression as well as attenuation as one of our design criteria--as we have in this exercise--we encounter a limit as to how much we may increase the mutual coupling among elements. All of the arrays have the same taper ratio of forward director to reflector: 0.67. (In fact, the values range only from 0.6698 to 0.6699.) However, the sidelobe structures are not identical.



Sidelobe Development: 20-Element OWA Yagi: 4 Versions Using Compression Scaling
All Patterns at 146 MHz (Design Frequency)

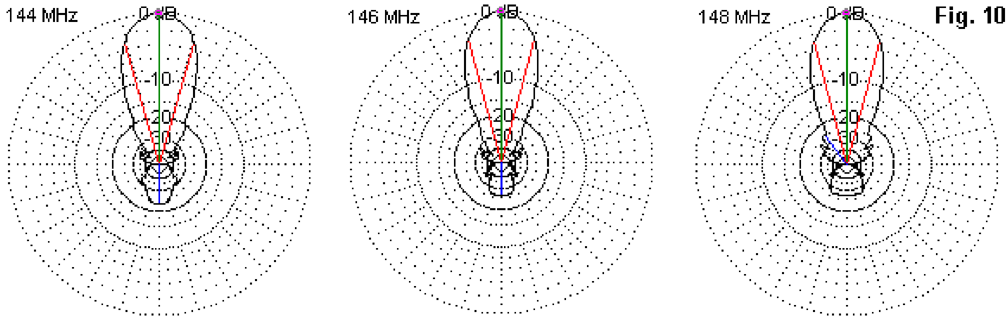
Fig. 9

As we increase the mutual coupling among adjacent elements by virtue of the element diameter and the element spacing, we can notice the incipient development of a new lobe. See **Fig. 9**. It shows itself as a shifting "bulge" in the forward patterns of the arrays using larger than 3/16" elements. In the rearward patterns, the main rear lobe corners are actually sidelobes for the purposes of counting. In the 0.75" version of the array, we can clearly count 5 sidelobes. Although this number remains 1 less than we find in our comparators, the DL6WU and the VK3AUU, the emergence of a new lobe also signals a reduction in the average sidelobe attenuation across the entire band.

Hence, our increase in gain via increased mutual coupling comes at a price, despite the maintenance of the element taper value. At a certain point in the process of increasing the coupling, we begin to lose the advantages of the element taper.

Perhaps the version of the array with the best all-round performance (including sidelobe suppression and attenuation with the more standard performance categories) is the one using 0.5" elements. **Fig. 10** shows the free-space E-plane (azimuth) patterns for this array across the 2-meter band at frequencies corresponding to those in the table of performance values.

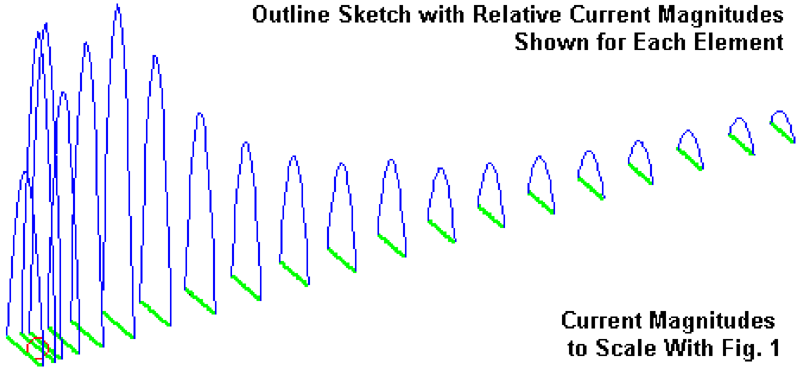
Fig. 10



Free-Space E-Plane Patterns: 0.5" Compressed Scaled 20-Element OWA Yagi

As a rough measure of the increase in mutual coupling, you may compare **Fig. 1** for our original array with 3/16" elements to **Fig. 11** for the version with 0.5" diameter elements. The increased relative current magnitude on the forward directors should be relatively clear.

Fig. 11



20-Element OWA Yagi With 0.5" Elements
Outline Sketch with Relative Current Magnitudes
Shown for Each Element

Current Magnitudes
to Scale With Fig. 1

However, we are still a dB below the gain of the DL6WU and VK3AUU arrays. Certainly, we can go through further iterations to further increase the array's gain while preserving the sidelobe suppression. However, it is unlikely that we shall attain full gain with full sidelobe suppression without significant elements of re-design. For example, it is not immediately clear how to increase the element population in balance with an element taper that will both attenuate existing sidelobes and suppress further sidelobe development while improving gain and sustaining front-to-back performance.

One Last Experiment in the Series

If we can scale element diameters upward, perhaps we may return to our initial 3/16" diameter elements by scaling downward from the 0.5" version of the array. Actually, the optimizing process required 3 steps and remains imperfect. First, I applied the standard element diameter-to-length equations for a new set of values. Next, I did some compression scaling--in this case, expansion scaling--to re-center the performance values. Finally, I re-adjusted the core elements to obtain a 50-Ohm SWR curve with values no higher than 1.2:1. The following table compares the dimensions of the original and the final versions of 3/16" 20-element OWA Yagis.

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20-Element 0.1875" Diameter Element OWA Yagis: Original and Revised

Note: All dimensions in inches.

Element	**Original Cumulative Spacing**	**El. Dia. 0.1875"**	**Revised Cumulative Spacing**	**El. Dia. 0.1875"**
Reflector	**----**	**40.90**	**----**	**40.90**
Driver	**8.79**	**39.50**	**8.79**	**39.50**
Director 1	**13.47**	**37.00**	**13.47**	**37.06**
Director 2	**25.38**	**36.33**	**25.37**	**36.48**
Director 3	**40.72**	**36.40**	**40.35**	**36.54**
Director 4	**61.38**	**36.21**	**60.56**	**36.41**
Director 5	**86.49**	**35.20**	**85.10**	**35.61**
Director 6	**116.00**	**34.30**	**113.96**	**34.90**
Director 7	**146.00**	**33.60**	**143.87**	**34.34**
Director 8	**178.40**	**32.90**	**174.96**	**33.79**
Director 9	**210.00**	**32.20**	**205.85**	**33.25**
Director 10	**243.00**	**32.20**	**238.11**	**33.25**
Director 11	**276.00**	**30.80**	**270.38**	**32.15**
Director 12	**309.00**	**30.40**	**302.64**	**31.83**
Director 13	**342.00**	**30.00**	**334.90**	**31.52**
Director 14	**375.00**	**29.20**	**367.16**	**30.88**
Director 15	**408.00**	**28.80**	**399.42**	**30.57**
Director 16	**441.00**	**28.40**	**431.68**	**30.25**
Director 17	**475.00**	**28.40**	**464.92**	**30.25**
Director 18	**502.00**	**27.40**	**491.32**	**29.49**

. . . .

Since the initial mode of re-scaling was application of standard scaling equations, the final revised beam is imperfect. It has an element taper of 0.72, which is below the values for the DL6WU and VK3AUU arrays, but well above the taper in the compression-scaled models. As we shall see, this difference makes a difference in the modeled performance data.

Modeled Performance: Revised 20-Element OWA Yagi

0.1875" Diameter Elements: Boom length 6.08 wavelengths

Parameter	**144 MHz**	**146 MHz**	**148 MHz**
Gain dBi	**16.03**	**16.39**	**16.20**
180-deg F-B	**24.53**	**27.92**	**24.86**
Front-Sidelobe	**29.26**	**26.20***	**23.80***
Impedance (R+/-jX)	**42.7 + j 3.7**	**45.6 + j 7.5**	**47.3 - j 7.7**
50-Ohm SWR	**1.19**	**1.20**	**1.18**

Note: * means the mergence of a new lobe.

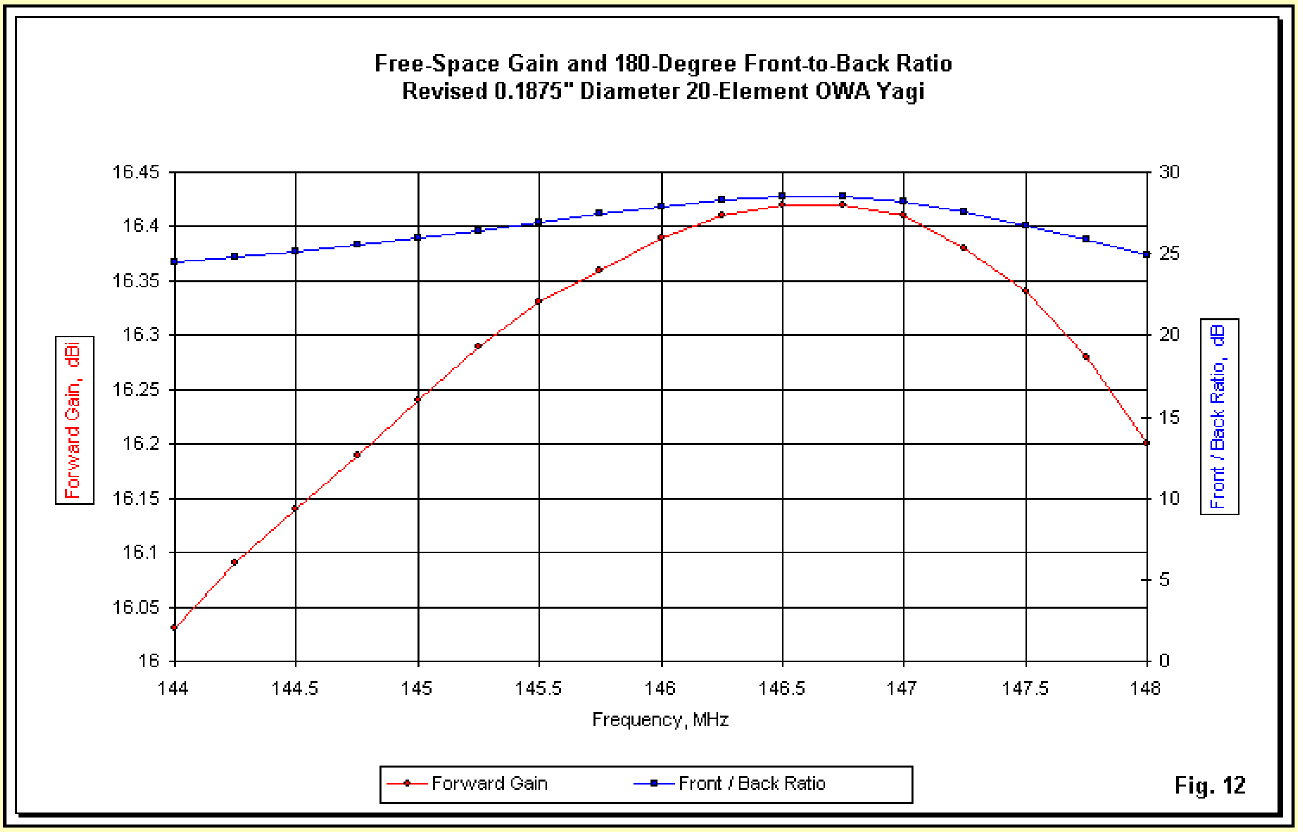
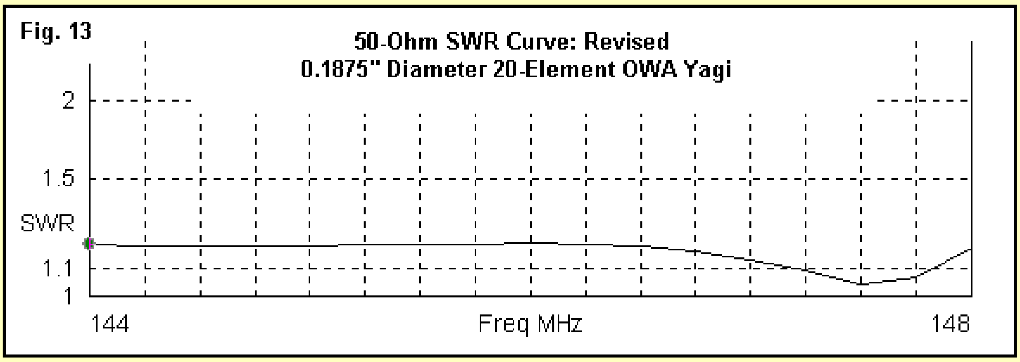


Fig. 12

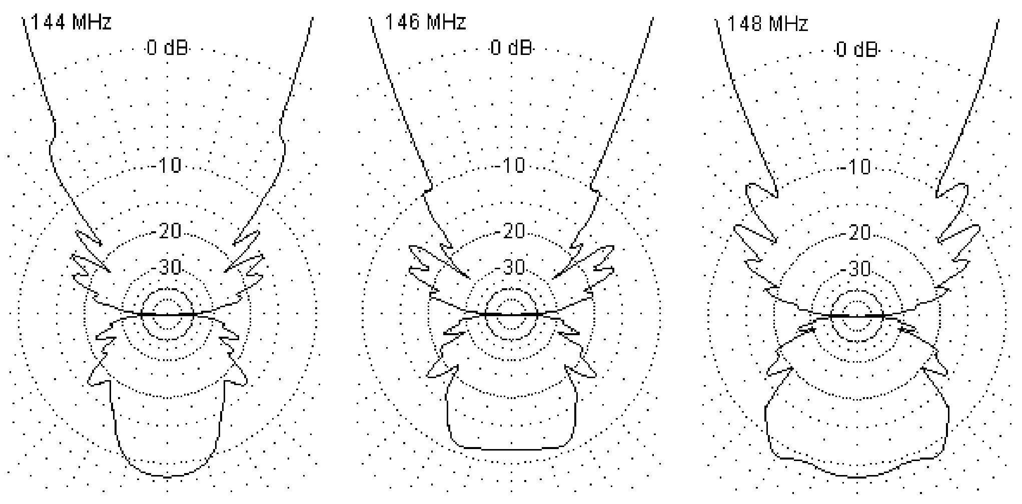
Fig. 12 shows the free-space gain and 180-degree front-to-back ratio across the band. The peaks are just above the design frequency. The front-to-back ratio shows roughly equal values at the band edges. The gain values show another small increment of increase beyond those of the 0.5" array version on which this design is based.

Fig. 13



The 50-Ohm SWR curve is pure OWA in its shape and low values across the band, as **Fig. 13** clearly illustrates. The deepest dip at 147.5 MHz is correctly placed.

However, the new taper value of 0.72 has taken its toll. See **Fig. 14**.



Sidelobe Development: Revised 20-Element OWA Yagi

Fig. 14

The increased taper value allows us to count 5 sidelobe peaks or bulges in both the forward and rearward directions for each of the 3 sampled patterns. Although at 144 MHz, we have a front-to-sidelobe ratio that reflects the best OWA values, the sidelobe attenuation at 146 MHz is 4 dB lower than the value for the 0.5" compressed-scaling array. For maximum sidelobe suppression and attenuation, the 0.5" diameter element version of the largest of our OWA series Yagis remains unsurpassed. . .for the moment.

Conclusion

Our initial task was simply to extend the OWA series of Yagis to 20 elements. However, the curiosities left by the results of that project have led us a considerable distance away from Yagis to build into the basic properties of Yagis. Some of these properties--for example, sidelobe suppression in contrast to simple attenuation--may have no immediate implications for practical antenna construction and use. However, these notes do indicate some directions for further investigation into the inter-relationship of the entire set of Yagi properties, if for no other reason than to understand them better.

Some of the properties are physical. This list includes the director structure algorithm, the element length taper, and the overall element population for a given boom length. Some of the properties are electrical, including forward gain, sidelobe attenuation, sidelobe suppression (or development), and mutual coupling. We may add to this list the various ways in which we construct the core to achieve a given feedpoint impedance over a considerable passband and the role of the core in establishing the positions of gain and front-to-back peaks. With this number of variables--plus others not listed or not yet appreciated--it is unlikely that Yagi development has reached its final stage. We have much more to learn before we can justify a claim that an ultimate Yagi is in hand. However, we are closer to being able to tailor a Yagi design for a more complex set of operational specifications.

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